Execution Plan for Small Projects

at the
Collider-Accelerator Department
at
Brookhaven National Laboratory
Upton, NY

for the
U.S. Department of Energy
Office of Science
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CHANGE LOG*

Revision	Affected Pages	Effective Date
0	entire document	Feb-11

***This change log is for the main document. For changes to an attachment, please go to the attachment in question.**

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1 INTRODUCTION

Brookhaven National Laboratory (BNL), located in Upton, NY, is owned by the U.S. Department of Energy (DOE) and operated by Brookhaven Science Associates (BSA) under the U.S. Department of Energy Contract No. DE-AC02-98CH10886. The flagship Nuclear Physics facility at BNL is the Relativistic Heavy Ion Collider (RHIC).

The Execution Plan for Small Projects (EPSP) describes the coordination of efforts of project teams at the Collider-Accelerator Department (C-AD) to ensure that projects are completed on time and within budget. Attachments to this document define the scope, work breakdown structure (WBS) and schedule for project-like initiatives which fall below the $5M threshold the DOE uses to define projects (reference DOE Order 413.3A).

2 MANAGEMENT

Funding for these projects will be directed through BNL's Collider-Accelerator Department. Fiscal and management responsibility for fabrication of the projects will reside with the Chairman, Thomas Roser.

Responsibilities

The Chairman for the Collider-Accelerator Department at BNL shall be administratively and fiscally responsible for the projects. This encompasses the following:

- Provides overall management oversight for all aspects of the projects.
- Appoints the Project Manager.
- Approves key personnel appointments made by the Project Manager.
- Approves major subcontracts recommended by the Project Manager.
- Ensures that adequate staff and resources are available to complete the projects in a timely and cost effective manner (within constraints of the budget provided).
- Ensures that the projects have demonstrated that they meet the functional requirements.
- Provides documentation and access to information necessary for operation of the projects at other sites, if applicable.
- Ensures the work is performed safely and in compliance with the ISM rules.

The Program Manager:

- Manages of all aspects of the project
- Appoints key personnel
- Recommends major subcontractors
- Estimates staff and resources to complete the project
- Leads the technical design to meet the functional requirements
- Develops risk management plans
- Provides technical and project documentation
- Ensures compliance with all environmental, safety, and health rules
- Schedules safety and performance reviews

3 ANALYSES, ASSESSMENTS AND PLANS

3.1 Environment, Safety and Health

3.1.1 Purpose of the ESSH Chapter

The purpose of this chapter is to briefly describe the rigorous environmental protection, safety, security, health and quality (ESSH) activities associated with the projects that will be completed prior to commencement of construction, commissioning and operations.

3.1.2 Review of ESSH Issues Associated with Project Design

The Collider-Accelerator Department's Radiation Safety Committee will review facility-shielding configurations (if applicable) to assure that the shielding has been designed to:

- Prevent contamination of the ground water.
- Limit annual site-boundary dose equivalent to less than 5 mrem.
- Limit annual on-site dose equivalent to inadvertently exposed people in non-Collider-Accelerator Department facilities to less than 25 mrem.
- Limit dose equivalent to any area where access is not controlled to less than 20 mrem during a fault event.
- Limit the dose equivalent rate to radiation-workers in continuously occupied locations to ALARA but in no case greater than 0.5 mrem in one hour or 20 mrem in one week.
- Limit the annual dose equivalent to radiation workers where occupancy is not continuous to ALARA, but in no case to exceed 1000 mrem.

In addition to review and approval by the Radiation Safety Committee, the Radiation Safety Committee Chair or the ESHQ Associate Chair must approve final shielding drawings. Shielding drawings are verified by comparing the drawings to the actual configuration. Radiation surveys and fault studies are conducted after the shielding has been constructed in order to verify the adequacy of the shielding configuration. The fault study methodology that is used to verify the adequacy of shielding is described and controlled by Collider-Accelerator Department procedures.

The DOE ESHQ requirements applicable to Small Projects are listed in Table 3-1. All hazards, including radiological hazards, associated with DOE accelerator facilities are addressed comprehensively in DOE Order 420.2A, Safety of Accelerator Facilities. Appropriate and adequate protection of workers, the public, and the environment from ionizing radiation is also covered under 10CFR1035, "Occupational Radiation Protection," which applies to all DOE facilities regardless of the source and type of ionizing radiation. The C-A Department implements the DOE requirements indicated in Table 3-1 using procedures and training. At the BNL level, the Standards Based Management System (SBMS) is used to keep DOE requirements current and to flow requirements down to the Department level. At the C-A Department level, SBMS requirements are flowed down into routine operations procedures. All ESHQ requirements and hazard controls are documented in detail in the C-A Operational Procedures (OPM).

In order to meet the requirements in DOE Order 420.2A, Safety of Accelerator Facilities, C-AD will incorporate a description and safety assessment of new equipment into the current Safety Assessment Document (SAD) for C-AD. At the appropriate time, the C-A Department will obtain an approved Accelerator Safety Envelope for new equipment from DOE and perform an Accelerator Readiness Review in accord with Order 420.2A prior to commissioning and operations.

Table 3-1 Current DOE ESHQ Requirements for BNL Accelerators

Topic	DOE Requirements Document
Authorization Basis Documents	DOE O 420.2B, Safety of Accelerator Facilities DOE O 420.1A, Facility Safety (Natural Phenomenon and Fire Protection Sections)
Conduct of Operations	DOE O 54100.19 Chg 2, Conduct of Operations Requirements for DOE Facilities
Quality Assurance	DOE O 414.1B, Quality Assurance
Maintenance Management	DOE O 430.1B, Real Property Asset Management DOE O 430.2A, Departmental Energy And Utilities Management
Training and Qualification Programs	DOE O 54100.20A Chg 1, Personnel Selection, Qualification, and Training Requirements for DOE Nuclear Facilities
Radiation Protection	Title 10, Code of Federal Regulations, Part 1035, Occupational Radiation Protection
Transportation and Packaging	DOE O 460.2 Chg 1, Departmental Materials Transportation and Packaging Management DOE O 460.1B, Packaging and Transportation Safety
Worker Protection	DOE O 440.1A, Worker Protection Management for DOE Federal and Contractor Employees
Environmental Protection	DOE O 450.1, Environmental Protection Program DOE O 451.1B Chg 1, National Environmental Policy Act Compliance Program - Change 1
ESH Reporting	DOE O 231.1A, Environment, Safety, and Health Reporting
ESH Standards	DOE O 54100.4 Chg 4, Environmental Protection, Safety, and Health Protection Standards
Accident Investigation	DOE O 225.1A, Accident Investigations
Radioactive Waste Management	DOE O 435.1 Chg 1, Radioactive Waste Management

The C-A Department conforms to the requirements of ISO 14001, Environmental Management System, and OHSAS 18001, Occupational Safety and Health Management System, and achieves third-party registration for these internationally recognized management systems. Thus, in addition to DOE requirements, documentation of environmental protection and occupational safety and health programs for new facilities will be prepared and audited by independent parties. This documentation will include:

- Environmental Process Evaluations for all processes with significant environmental aspects.

- Facility Risk Assessments for all facilities and areas.
- Job Risk Assessments for all jobs.

DOE O 420.1A, Facility Safety, has two sections that are applicable to accelerator facilities: Natural Phenomenon and Fire Protection Sections. DOE STD-1020-2002, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities, describes the Performance Criteria (PC) to be used for evaluating building design for earthquake, wind and flood phenomena. DOE-STD-1020-2002 employs the graded approach in assigning PC categories to DOE buildings. The graded approach enables cost-benefit studies to be used to address categorization. BNL is currently using PC1 for all existing C-AD facilities for life safety issues. All Small Projects will be reviewed and categorized according to their own unique details.

Significant environmental aspects of new equipment could include:

- Excavation
- Chemical Storage/Use
- Liquid Effluent
- Hazardous Waste
- Radioactive Waste
- Radiation Exposures
- New or Modified Federal/State Permits

If cooling water is used, the existing New York State Pollutant Discharge Elimination System (SPDES) permit would be revised, as necessary, based on the disposition of cooling tower discharge. Discharge of contaminants to the ground or to the sanitary system would be neither planned nor expected. The closed loop cooling system would be connected to the cooling tower via a heat exchanger. Cooling-tower water would be treated either with ozone or with biocides and rust inhibitors, and would meet all SPDES effluent limits.

3.1.3 ESSH Plans for Construction

All requests for goods or services will be processed through a formal and well-documented system of review to incorporate any special ESSH requirements of the contractor or vendor. BNL will review the proposed contract scope of work using the Work Planning and Control for Experiments and Operations Subject Area (Work Planning & Control). The building modification and utility drawings for new equipment will be sent to the BNL's Safety and Health Services Division for review by the appropriate Environment, Safety and Health (ES&H) disciplines.

C-AD will define the scope of work with sufficient detail to provide reviewers and support personnel with a clear understanding of what is needed, expected, and required. This will include the type of work to be performed, location of work, defined contract limits, allowed access routes, and any sensitive or vulnerable laboratory operations or infrastructure that may be impacted by this work. The C-AD will ensure that facility hazards are characterized and inventoried specific to the expected construction location and activities.

The C-AD will ensure that minimum ESSH competency requirements for contractors are detailed and provided to the Procurement & Property Management Division (PPM). PPM will include those requirements in the bid and contract documents to qualify contractors for award. Competency requirements will be consistent with the project, facility and job to be performed.

3.1.4 ESSH Plans for Commissioning, Operations and Decommissioning

The Collider-Accelerator Department already identifies hazards and associated on-site and off-site impacts to workers, the public and the environment from the C-AD accelerator facilities for both normal operations and credible accidents. Sufficient detail was provided to DOE in the current C-AD Safety Assessment Document (SAD) to ensure that C-AD has performed a comprehensive hazard and risk analysis. The amount of descriptive material and analysis in the SAD relates to both the complexity of the facility and the nature and magnitude of the hazards. In addition, the SAD provides an understanding of radiation risks to the workers, the public and the environment.

The C-AD SAD follows the generally accepted principles identified in DOE Order 420.2B. All equipment and systems created/upgraded by a Small Project will be the subject of a separate and distinct Hazard Analysis. The C-AD SAD will be updated, as required.

3.2 PROJECT QUALITY ASSURANCE PROGRAM

3.2.1 Program

The project, through the Collider-Accelerator (C-A) Department, shall adopt in its entirety the BNL Quality Assurance (QA) Program (Quality Requirements, Graded Approach for). This QA Program describes how the various BNL management system processes and functions provide a management approach which conforms to the basic requirements defined in DOE Order 414.1B, Quality Assurance.

The quality program embodies the concept of the "graded approach" i.e., the selection and application of appropriate technical and administrative controls to work activities, equipment and items commensurate with the associated environment, safety and health risks and programmatic impact. The graded approach does not allow internal or external requirements to be ignored or waived, but does allow the degree of controls, verification, and documentation to be varied in meeting requirements based on environment, safety and health risks and programmatic issues.

The BNL QA Program shall be implemented within the projects using C-A QA implementing procedures. These procedures supplement the BNL Standards Based Management System documents for those QA processes that are unique to the C-A Department. C-A QA procedures are developed by C-A QA and maintained in the C-A Operations Procedures Manual (Chapter 13: ESSHQ Division).

The C-A QA philosophy of adopting the BNL Quality Program and developing departmental procedures for the implementation of quality processes within C-A ensures that complying with requirements will be an integral part of the design, procurement, fabrication, construction and operational phases of the projects.

A Quality Representative has been assigned to serve as a focal point to assist C-A management in implementing QA program requirements. The Quality Representative has the authority, unlimited access, both organizational and facility, as personnel safety and training allows, and the organizational freedom to: assist line managers in identifying potential and actual problems that could degrade the quality of a process/item or work performance, recommend corrective actions, and verify implementation of approved solutions. All C-A personnel have access to the Quality Representative for consultation and guidance in matters related to quality.

3.2.2 Personnel Training and Qualifications

The BNL Training and Qualification Management System (Training and Qualifications) within the Standards Based Management System supports C-A management's efforts to ensure that personnel working on the projects are trained and qualified to carry out their assigned responsibilities. The BNL Training and Qualification Management System (Training and Qualifications) is implemented within the C-A Department with the C-A Training and Qualifications Plan of Agreement (Training Plan[1]).

3.2.3 Documents and Records

The BNL Records Management System (Records Management) and controlled document Subject Areas within SBMS, supplemented by C-A procedures, provide the requirements and guidance for the development, review, approval, control and maintenance of documents and records.

C-A documents encompass technical information or instructions that address important work tasks, and describe complex or hazardous operations. They include plans, and procedures, instructions, drawings, specifications, standards and reports.

3.2.4 Work Process

Work is performed employing processes deployed through the BNL SBMS. SBMS Subject Areas are used to implement BNL-wide practices for work performed. Subject Areas are developed in a manner that provides sufficient operating instructions for most activities. However, C-A management has determined that it is appropriate to develop internal procedures to supplement the SBMS Subject Areas. These C-A procedures are bounded by the requirements established by the BNL Subject Areas.

Group leaders and technical supervisors are responsible for ensuring that employees under their supervision have appropriate job knowledge, skills, equipment and resources necessary to accomplish their tasks. Where applicable, contractors and vendors are held to the same practices.

[1] http://www.c-ad.bnl.gov/ESSHQ/SND/Training/trainplan.pdf C-A Department Training and Qualifications Plan of Agreement.

3.2.5 Design

Design planning shall establish the milestones at which design criteria, standards, specifications, drawings and other design documents will be prepared, reviewed, approved and released. The design criteria shall define the performance objectives, operating conditions, and requirements for safety, reliability, maintainability and availability, as well as the requirements for materials, fabrication, construction, and testing. Appropriate codes, standards and practices for materials, fabrication, construction, testing, and processes shall be defined in the design documentation. Where feasible, nationally recognized codes, standards and practices shall be used. When those are either overly restrictive, or fall short of defining the requirements, they shall be modified, supplemented, or replaced by BNL specifications.

Specifications, drawings and other design documents present verifiable engineering delineations in pictorial and/or descriptive language representations of parts, components or assemblies for the project. These documents shall be prepared, reviewed, approved and released in accordance with C-A procedures. Changes to these documents shall be processed in accordance with the C-A configuration management program.

3.2.6 Procurement

Personnel responsible for the design or performance of items or services to be purchased shall ensure that the procurement requirements of the purchase request are clear and complete. Using the graded approach, potential suppliers of critical, complex, or costly items or services shall be evaluated in accordance with predetermined criteria to ascertain that they have the capability to provide items or services which conform to the technical and quality requirements of the procurement. The evaluation shall include a review of the supplier's history with BNL or other DOE facilities, or a pre-award survey of the supplier's facility. C-A personnel shall ensure that the goods or services provided by the suppliers are acceptable for intended use.

3.2.7 Inspection and Acceptance Testing

The BNL Quality Management System within the SBMS, supplemented by C-A procedures, provides processes for the inspection and acceptance testing of an item, service or process against established criteria and provides a means of determining acceptability. Based on the graded approach, the need and/or degree of inspection and acceptance testing shall be determined during the activity/item design stage. Inspection/test planning has as an objective the prompt detection of non-conformances that could adversely affect performance, safety, reliability, schedule or cost.

4 CONTROLS AND REPORTS

The Small Projects' cost and progress information is reviewed monthly by the Project Managers and the Department Chairman. Monthly milestone status reports are provided as required for the American Recovery and Reinvestment Act (ARRA) funded projects. Quarterly reports are provided to DOE-NP. Technical performance is monitored throughout the project to ensure conformance to approved functional requirements. Design reviews and performance testing of the completed systems are used to ensure that the equipment meets the functional requirements.

5 ATTACHMENT I — STOCHASTIC COOLING ARRA AIP

Revision	Affected Pages	Effective Date
0	entire attachment	Feb-11
1	12 - 16	Aug-11

Wolfram Fischer Date: 8/16/2011

Wolfram Fischer
Associate Chair for Accelerators
Collider-Accelerator Department
Brookhaven National Laboratory

Date: 8/25/11

James Sowinski
Program Manager
Nuclear Physics Facilities
Office of Nuclear Physics

RHIC Horizontal Stochastic Cooling ARRA Accelerator Improvement Project

Extending the stochastic cooling system for RHIC to the horizontal planes will increase the integrated luminosity for physics production. The luminosity is a function of three main variables, ions per bunch, lattice beta function at the interaction point, and beam emittance. The first two variables have been optimized to their practical limit and the beam emittance, although optimized at the beginning of a production store is

RHIC Horizontal Stochastic Cooling ARRA Accelerator Improvement Project

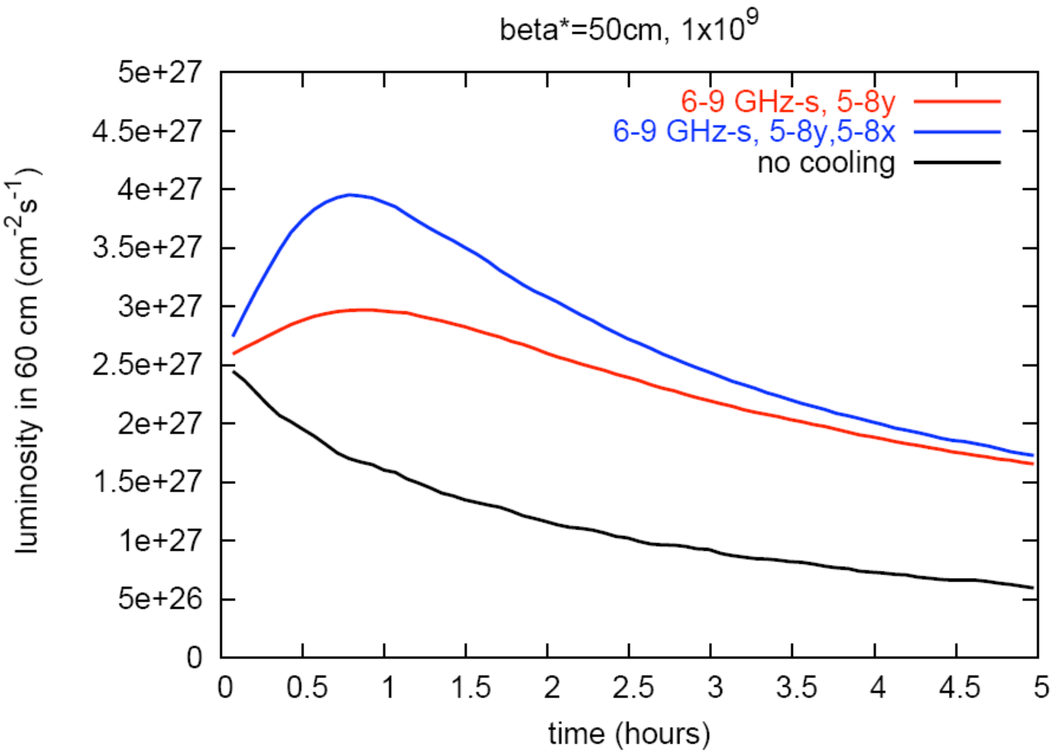
Extending the stochastic cooling system for RHIC to the horizontal planes will increase the integrated luminosity for physics production. The luminosity is a function of three main variables, ions per bunch, lattice beta function at the interaction point, and beam emittance. The first two variables have been optimized to their practical limit and the beam emittance, although optimized at the beginning of a production store is continuously degraded during the course of a store by intra-beam scattering (IBS), which causes the luminosity to fall to the point that the store is terminated, so that the collider must be refilled with fresh beam. The drop off of instantaneous luminosity and the time it takes to refill and ramp the new beam make the integrated luminosity much less than the peak instantaneous luminosity. Stochastic cooling counteracts IBS by decreasing beam emittance thus keeping the luminosity high.

IBS at 100 GeV/nucleon in RHIC increases the emittance in all three phase space planes, longitudinal, vertical, and horizontal. Stochastic cooling requires a separate cooling system for each plane. A system is comprised of a beam pickup, signal processing electronics, and a high voltage broadband kicker. These components couple to only one beam coordinate at a time so that the hardware of the cooling system must be replicated for each plane. We have implemented cooling systems for two of the three planes (longitudinal and vertical), and the present project is to finish the full system by implementing horizontal cooling.

The technology of the equipment has been developed and tested in the previously completed systems. Special measures were developed to satisfy the unique requirements for cooling bunched beam in a high energy collider [1]. To reach a useful cooling rate the system must operate at high frequency. Our longitudinal cooling covers 6 to 9 GHz bandwidth and the first transverse system uses 5 to 8 GHz. RF power for the kickers is the dominant hardware cost for these systems. The kickers are optimized for the bunched-beam nature of the collider [2]. They are comprised of narrowband cavities that can generate high voltage with only a few watts of input power by accumulating energy from the amplifiers in the time interval between the bunches. The effective bandwidth of the system is 3 GHz even though the actual bandwidth of the narrowband kickers is much smaller. The kicker-amplifier package is a modular design. The specific dimensions of the microwave cavities of the kicker will be tailored for orientation in the new plane, but the fabrication technique and the installation equipment will use the existing design.

One of the main problems for stochastic cooling of bunched beam is the issue of coherent lines in the Schottky spectrum [3, 4]. This was studied extensively with ion beams cooled in RHIC, compared to protons that are stored in other colliders. The studies led to the development of signal processing electronics that can cope with the coherent lines that are encountered in cooling ions. The electronics have proven effective in the first cooling system that was used in the longitudinal plane, and will be repeated in this new design.

There are strong interactions in the beam between the different phase space planes. Firstly, IBS couples the cooling rate between the planes because reducing the emittance in one plane will increase the IBS growth rate in the other. Secondly, betatron coupling will tend to transfer emittance from one transverse plane to the other. Cooling rates must be optimized to strike a balance between emittances and IBS growth rates. This aspect of the design has been studied via simulations. Complete simulation is only practical if an accurate scaling formulation is applied to keep the number of macroparticles manageable. The cooling time is proportional to the number of particles in the beam. One can scale down the number of particles for the simulation and scale up the resulting cooling time. IBS kicks are scaled to the local particle density and applied randomly to each turn of the macroparticles. The approach has been benchmarked by comparing predictions with measured results from longitudinally cooled gold beam[5]. The simulations show that adding cooling in both transverse planes, and balancing the cooling rate between longitudinal and transverse all add to the integrated luminosity. Figure 1 illustrates the result of a simulation comparing no cooling, the present system with only the vertical transverse plane cooled, and a complete cooling system. An average luminosity of ~3×10^{27} $cm^{-2}s^{-1}$ in a 5 hour store is expected.



References

[1] J. M. Brennan, M. Blaskiewicz, and F. Severino, Proceedings of EPAC 2006, Edinburgh, Scotland, p2968

[2] J. M. Brennan, and M. Blaskiewicz, Bunched Beam Stochastic Cooling Project for RHIC, Beam Cooling and Related Topics, COOL 05, American Institute of Physics 0-7354-0314-7/06 p.185

[3] G. Jackson, Particle Accelerator Conference, 1991, p1758

[4] D. Boussard et al. CERN Accelerator School 1983, p197

[5] M. Blaskiewicz, J.M. Brennan, and F. Severino, PRL 100, 174802 (2008)

Project Management

The Federal Program Manager for the Stochastic Cooling project is James Sowinski and the Contractor Project Manager at BNL is Alex Zaltsman.

Technical Scope and Deliverables

The scope of this project is to engineer, procure and install a horizontal Stochastic Cooler and associated equipment in both the RHIC Blue and Yellow rings. Each ring contains one pickup plus 2 vacuum vessels with 8 cavities per vessel. The major procurements include amplifiers, electronics and vacuum vessel assemblies.

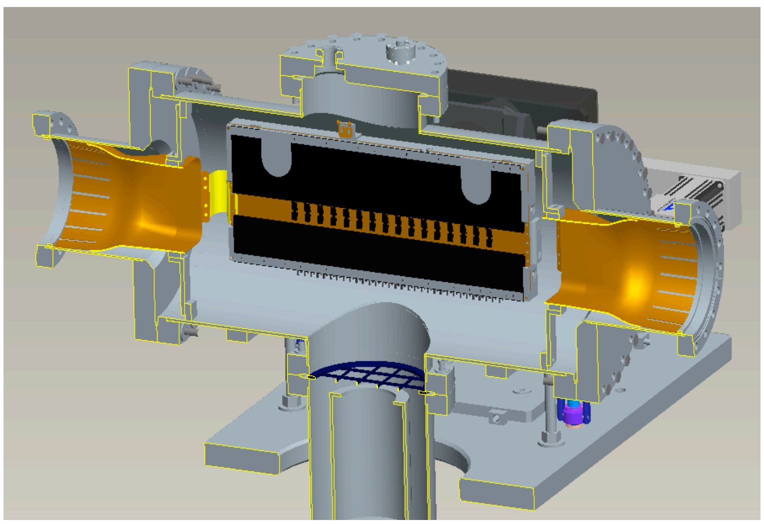


Figure 1: Horizontal stochastic cooling pick-up design.

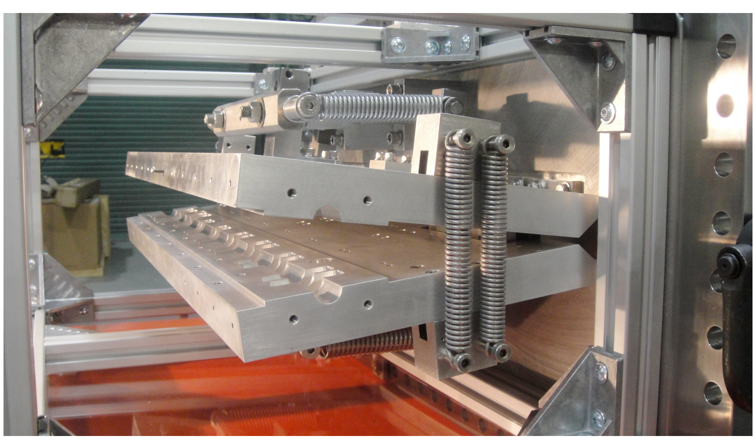


Figure 2: Prototype for a horizontal stochastic cooling kicker.

Successful project completion is defined as: All components are installed in the RHIC ring and the following critical parameters were verified: (1) All cavities are within the 3dB bandwidth of their operating frequency before vacuum vessel closure. (2) The power amplifiers have the specified gain (46dB) and power (46dBm).

Cost and Schedule

The Total Project Cost for the Stochastic AIP is $4M in AY dollars and is being funded by American Recovery and Reinvestment Act (ARRA) funds. All funding has been received. When complete it is estimated that approximately $0.5M (~15%) will have been spent on labor, with the remaining $3.5M (~85%) spent on material and equipment. There is no project contingency.

Milestones

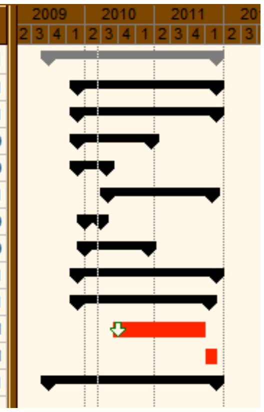
The chart below shows the project milestones, some of which are reportable for ARRA funding purposes.

Stochastic Cooling Plane Milestones	planned mo/yr	actual / forecast mo/yr	ARRA milestones
Obligate Funding to BNL	Jun-09	Jun-09A	x
Start Design	Jun-09	Jun-09A	x
Begin Purchasing	Jul-09	Aug-09A	x
Start Fabrication	May-10	Feb-10A	x
Water Chillers available for Installation	May-10	Apr-10A	-
50% of cavities tested and sent for plating	Sep-10	Jun-10A	-
Begin Construction	Nov-10	Jul-10A	x
Kicker tanks received from manufacturer	1QFY11	Nov-10A	-
LLRF installation 50% complete	2QFY11	Mar-11A	-
Start Assembly of Cavity and Tanks	Mar-11	Nov-10A	x
Pick up tanks assembled and tested	3QFY11	Jun-11A	-
LLRF installation complete	3QFY11		-
Cables 50% complete	3QFY11	Jun-11A	-
Begin Installation	Aug-11	Jul-11A	x
Cables 100% complete	4QFY11		-
Accelerator Systems Safety Review	1QFY12		-
Radiation Safety Review	1QFY12		-
Complete installation	1QFY12		-
Start Commissioning	Nov-11		x
Planned Early Finish Date	2QFY12		-
Project Complete	May-12		x

Schedule

The Project is working to the Early Finish dates shown in the schedule below with 6 months of float to the Project completion date.

	Task Name	Start	Finish
0	**AIP Stimulus Project**	**Thu 6/25/09**	**Wed 11/30/11**
1	**Horizontal Stochastic Cooling**	**Mon 11/30/09**	**Wed 11/30/11**
2	**Blue and Yellow Rings**	**Mon 11/30/09**	**Fri 11/25/11**
3	**Vacuum Tanks**	**Tue 12/1/09**	**Mon 12/20/10**
21	**Amplifiers**	**Tue 12/1/09**	**Thu 4/29/10**
25	**Cables**	**Mon 5/3/10**	**Tue 11/1/11**
31	**Water Chillers**	**Thu 12/31/09**	**Fri 3/26/10**
35	**Pick-Up**	**Thu 1/7/10**	**Wed 12/1/10**
43	**Low Level RF (LLRF)**	**Mon 11/30/09**	**Fri 11/25/11**
50	**Instrumentation**	**Tue 12/1/09**	**Mon 10/17/11**
57	Installation	Tue 6/1/10	Fri 9/30/11
58	Commissioning (Ready for Beam)	Fri 9/30/11	Wed 11/30/11
59	**Milestones**	**Thu 6/25/09**	**Wed 11/30/11**



6 ATTACHMENT II — ELECTRON LENS ARRA AIP

Revision	Affected Pages	Effective Date
0	entire attachment	Feb-11
1	18, 21-23	Aug-11

Wolfram Fischer Date: 8/16/2011

Wolfram Fischer
Associate Chair for Accelerators
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Brookhaven National Laboratory

Date: 8/25/11

James Sowinski
Program Manager
Nuclear Physics Facilities
Office of Nuclear Physics

RHIC Electron Lens ARRA Accelerator Improvement Project

The polarized proton luminosity is limited by the beam-beam interaction, which leads to tune shifts and spreads in the beam. So far total beam-beam induced tune spreads of

0.015 with 2 beam-beam collisions were reached in RHIC, and bunches with 1 collision have better lifetimes than bunches with 2 collisions (see Figure 1).

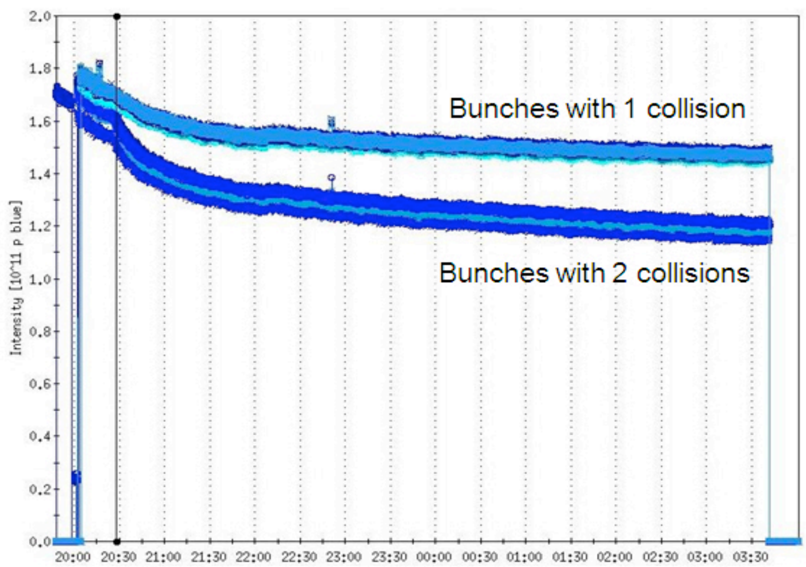

Figure 3: Beam lifetime of bunches with 1 and 2 head-on beam-beam collisions in RHIC (Run-8). Since most bunches encounter 2 collisions, up to 50% luminosity could be gained if the effect of the second beam-beam collision is compensated.

When the proton beams also collide with a low energy electron beam (electron lens), the beam-beam induced tune spread can be partially compensated. With such compensation, one can either increase the bunch intensity or decrease the beam emittance, leading to higher luminosity.

Complete head-on beam-beam compensation requires 3 conditions:

1. The amplitude dependent force exerted on a proton by the proton and electron beam is the same (i.e. both beams have a Gaussian profile).
2. The phase advance between the proton-proton and electron-proton collision is a multiple of π.
3. There are no nonlinearities between the proton-proton and electron-proton collision.

In practice these conditions can only be met approximately but even under imperfect compensation the tune spread can be reduced and the beam lifetime improved for large enough beam-beam parameters ξ.

The first and only attempt of head-on beam-beam compensation was at DCI, a 4-beam $e^+e^-e^+e^-$ collider, in the 1970s. It failed because of coherent instabilities. Such instabilities are not expected in RHIC because the beam-beam parameter in RHIC is an order of magnitude smaller than in DCI, and the electron beam of the lens cannot couple back to the proton beam. Beam-beam driven coherent instabilities have not limited the RHIC performance to date, and with electron lenses we expect an increase in the beam-beam parameter by not more than a factor of 2. Two electron lenses are installed in the Tevatron where they are used as gap cleaner, and have been shown to increase the beam lifetime of selected antiproton bunches suffering from PACMAN effects. The Tevatron electron lenses were not used as head-on beam-beam compensators (only one of the lenses had a Gaussian profile temporarily for test purposes). Within the US LHC Accelerator Research Program head-on beam-beam compensation is also under investigation for the LHC.

Simulations have shown that the head-on beam-beam effect should only be compensated partially. Our goal is to reduce the beam-beam induced tune spread only to values that can be accommodated in the tune diagram. Since the beam-beam parameter is only linearly dependent on the bunch intensity ($\xi \propto N_b$) but the luminosity quadratically ($L \propto N_b^2$), gains in ξ translate in about twice that amount in L.

The electron lenses were reviewed by the C-AD Machine Advisory Committee (03/23-25/2009), where it was stated, “the proposal for an operational demonstration is strongly supported”.

While the concurrent manufacture and installation of two lenses is optimal from a cost and operational standpoint, a single lens would yield half of the luminosity gain of two lenses. A lens installed in one beam would allow for an increase in the bunch intensity in the other beam. With two lenses the bunch intensity of both beams can be increased. The concurrent operation of 2 superconducting solenoids with fields of opposite polarity yields transparency for linear coupling and spin orientation. It allows changing the fields in the main solenoids without affecting the stored proton beam and greatly reduces dedicated commissioning time.

A list of reports on head-on beam-beam compensation in RHIC follows:

[1] W. Fischer (issue editor) and W. Chou (executive editor), "ICFA Beam Dynamics Newsletter No. 52 -- Current beam-beam problems", (2010).

[2] Y. Luo, W. Fischer and X. Gu, "Coupling effect on the proton optics from the electron lenses", BNL C-AD/AP/395 (2010).

[3] Y. Luo and W. Fischer, "6-D weak-strong beam-beam simulation study of proton lifetime in presence of head-on beam-beam compensation in the RHIC", BNL C-AD/AP/394 (2010).

[4] Y. Luo and W. Fischer, "Simulation study of dynamic aperture with head-on beam-beam compensation in the RHIC", BNL C-AD/AP/392 (2010).

[5] W. Fischer, Y. Luo, and C. Montag, "Bunch length effects in the beam-beam compensation with an electron lens", proceedings of the 2010 International Particle Accelerator Conference, Kyoto, Japan, pp. 4755-4757 (2010).

[6] C. Montag, W. Fischer, and D.M. Gassner, "Optimizing the beam-beam alignment in an electron lens using bremsstrahlung", proceedings of the 2010 International Particle Accelerator Conference, Kyoto, Japan, pp. 537-539 (2010).

[7] W. Fischer, E. Beebe, D. Bruno, A.V. Fedotov, D.M. Gassner, X. Gu, R.C. Gupta, J. Hock, A.K. Jain, R. Lambiase, Y. Luo, M. Mapes, W. Meng, C. Montag, B. Oerter, M. Okamura, A.I. Pikin, D. Raparia, Y. Tan, R. Than, J. Tuozzolo, and W. Zhang, "Status of the RHIC head-on beam-beam compensation project", proceedings of the 2010 International Particle Accelerator Conference, Kyoto, Japan, pp. 513-515 (2010).

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[9] C. Montag and W. Fischer, "Head on beam beam compensation investigation in an electron ion collider using weak strong simulations", Phys. Rev. ST Accel. Beams 12, 084001 (2009).
[10] W. Fischer, N.P. Abreu, R. Calaga, R. de Maria, Y. Luo, C. Montag, G. Robert-Demolaize, T. Sen, and H.J. Kim, "LHC beam-beam compensation studies at RHIC", proceedings of the 2009 Particle Accelerator Conference, Vancouver, Canada (2009).
[11] Y. Luo, N.P. Abreu, R. de Maria, W. Fischer, G. Robert-Demolaize, and E. McIntosh, "Weak-strong simulation of head-on beam-beam compensation in the RHIC", proceedings of the 2009 Particle Accelerator Conference, Vancouver, Canada (2009).
[12] A. Valishev, Y. Luo, and W. Fischer, "Summary of the LARP Mini-Workshop on Electron Lens Simulations at BNL", BNL C-A/AP/353 (2009).
[13] W. Fischer et al., "Long-range and head-on compensation studies in RHIC with lessons for the LHC", proceedings of the CARE-HHH Workshop 2008 - Scenarios for the LHC upgrade and FAIR, to be published as CERN Yellow report (2009).
[14] Y. Luo, G. Robert-Demolaize, N. Abreu, and W. Fischer, "Multi-particle weak-strong simulations of head-on beam-beam compensation in the RHIC", EPAC'08 (2008).
[15] N.P. Abreu et al., "The effect of head-on beam-beam compensation on the stochastic Boundaries and particle diffusion in RHIC", EPAC'08 (2008).
[16] Y. Luo et al., "Head-on beam-beam compensation with electron lenses in the Relativistic Heavy Ion Collider", EPAC'08 (2008).
[17] W. Fischer et al., "Summary of LARP Mini-Workshop on Beam-Beam Compensation 2007", BNL C-A/AP/291; ICFA Beam Dynamics Newsletter No. 44, pp. 220-225; proceedings of BEAM'07, CERN-2008-005, CARE-Conf-08-004-HHH (2008).
[18] Y. Luo and W. Fischer, "Outline of using an electron lens for the RHIC head-on beam-beam compensation", BNL C-A/AP/286 (2007).

Project Management

The Federal Program Manager for the Electron Lens ARRA AIP project is James Sowinski and the Contractor Project Manager at BNL is Wolfram Fischer.

Technical Scope and Deliverables

The project scope is to engineer, design, fabricate and test the components for one electron lens, such that the lens is ready for installation during a RHIC shutdown. Major fabrications include the onsite fabrication of a superconducting magnet and correctors, plus an electron gun and collector. Major procurements include 6 warm solenoids and 4 warm orbit correctors as well as power supplies for the gun, transport and collector.

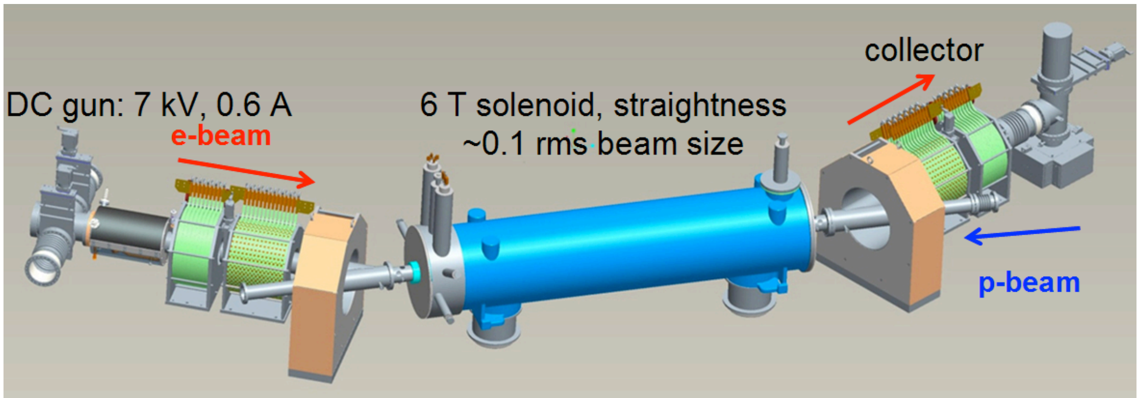

Figure 4: RHIC electron lens with gun, electron beam transport, main solenoid and collector. The electron interacts with the proton beam inside the main solenoid.

Successful completion of the project is defined as: All components are ready for installation in the RHIC interaction region and the following 2 critical parameters have been verified: (1) A minimum field of 5 T in the superconducting solenoid as measured in a vertical test. (2) 10% of the nominal electron beam current transported from the gun to the collector on a test bench with the superconducting solenoid.

Cost and Schedule

The Total Project Cost is \$4M in AY dollars, funded by American Recovery and Reinvestment Act (ARRA) funds. All ARRA funding has been received. It is estimated that approximately \$1M (25%) of the ARRA funds will be spent on labor and the remaining \$3M (75%) spent on material and equipment. There is no project contingency.

The current estimated cost by system is detailed in the table below.

1.0	Electron Lens ARRA AIP	$k
1.1	Funding Milestones	0
1.2	S/C Solenoid	1103
1.3	Warm Magnets	269
1.4	Electron Guns	47
1.5	Electron Collectors & Mechanical Supports	216
1.6	Power Supplies	1034
1.7	Vacuum System	579
1.8	Beam Instrumentation	458
1.9	Controls	154
1.10	Conventional Facilities	109
1.11	Installation Planning/Prep	31
	Total	4000

WBS 1.11 is Installation of utilities in FY11 and installation planning for FY12.

Milestones

The chart below shows the project milestones, some of which are reportable for ARRA funding purposes. Milestones related to the manufacture of the superconducting solenoid are shown as (SMD).

Electron Lens ARRA AIP Milestones	actual or planned*	ARRA milestones
Obligate Funding to BNL	Jun FY09A	x
Solenoid, including power supply ready to order	Jul-FY09A	x
Gun & Collector ready to order	Feb FY10A	x
Beam Transport ready to order	Jun FY10A	x
Diagnostics ready to order	Jul FY10A	x
Design Review for Superconducting Solenoid	Oct FY11A	
Electron Lens added to C-AD Safety Analysis Document	2QFY11A	
FY11 Installation tasks defined in schedule	2QFY11A	
1st delivery - warm solenoid	3QFY11A	
FY12 Installation tasks defined in schedule	3QFY11A	
Control System specified	Jun FY11A	x
Begin installation of utilities	4QFY11A	x
Block Corrector Coils Complete (SMD)	4QFY11	
Gun and collector manufactured complete	4QFY11	
Fringe Field Solenoid Coils Complete (SMD)	4QFY11	
Transport solenoids manufactured complete	1QFY12	
Dipole Trim Coils Complete	1QFY12	
Solenoid Vertical test (SMD)	2QFY12	x
Gun and collector test stand measurements complete	3QFY12	
All components tested and ready for installation	3QFY12	
Project complete	3QFY12	x

7 ATTACHMENT III — SECOND ELECTRON LENS AIP

Revision	Affected Pages	Effective Date
0	entire attachment	Feb-11
1	24-26	Aug-11

Wolfram Fischer Date: 8/16/2011

Wolfram Fischer
Associate Chair for Accelerators
Collider-Accelerator Department
Brookhaven National Laboratory

Date: 9/1/1

James Sowinski
Program Manager
Nuclear Physics Facilities
Office of Nuclear Physics

Project Management

The second electron lens is funded as an Accelerator Improvement Project. Federal Program Manager for the Second Electron Lens project is James Sowinski and the Contractor Project Manager at BNL is Wolfram Fischer. To take advantage of economies of scale this project is running concurrent with the Electron Lens ARRA AIP (Attachment II to this document).

Technical Scope and Deliverables

The project scope is to engineer, design, and fabricate one electron lens plus install two electron lenses (one fabricated with ARRA funds and this one fabricated as the Second AIP).
Major fabrications include the onsite fabrication of a superconducting magnet and correctors, plus an electron gun and collector. Major procurements include 6 warm solenoids and 4 warm orbit correctors as well as power supplies for the gun, transport and collector.

Successful completion of the project is defined as: All components are installed in the RHIC interaction region and the following 2 critical parameters were verified before installation: (1) A minimum field of 5 T in the superconducting solenoid as measured in a vertical test. (2) 10% of the nominal electron beam current transported from the gun to the collector on a test bench.

Cost and Schedule

The Total Project Cost is $3.1M in AY dollars, funded by Accelerator Improvement Project (AIP) funds. It is planned to fund $2M in FY2011 and $1.1M in FY2012. It is estimated that approximately $1.4M (45%) of the AIP funds will be spent on labor and the remaining $1.7M (55%) spent on material and equipment. Because the cost of the superconducting solenoid far exceeded the estimate there is currently no project contingency.

The current estimated cost by system is detailed in the table below.

1.0	Second Electron Lens AIP	$k
1.1	Funding Milestones	0
1.2	S/C Solenoid	394
1.3	Warm Magnets	187
1.4	Electron Guns	21
1.5	Electron Collectors & Mechanical Supports	144
1.6	Power Supplies	778
1.7	Vacuum System	579
1.8	Beam Instrumentation	703
1.9	Controls	154
1.10	Conventional Facilities	109
1.11	Installation	31
1.12	Subsystem Test and Commissioning	0
	Total	**3,100**

WBS 1.12, Subsystem Test and Commissioning is shown as no cost because the effort is off-project (RHIC Operations).

Milestones

The chart below shows the project milestones. Milestones related to the manufacture of the superconducting solenoid are shown as (SMD).

Electron Lenses Milestones - AIP #2	**planned mo/yr**
Design Review for Superconducting Solenoid	Oct FY11A
Gun and collector manufactured complete	4QFY11
Block Corrector Coils Complete (SMD)	4QFY11
Yoke Assembly Complete (SMD)	2QFY12
Solenoid Vertical test (SMD)	3QFY12
Magnet Assembly Complete (SMD)	4QFY12
Begin tunnel installation	4QFY12
Tunnel installation complete	1QFY13
Project Complete	2QFY13